

# The National Geographic Magazine

AN ILLUSTRATED MONTHLY



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## CONTENTS

	PAGE
MODIFICATION OF THE GREAT LAKES BY GLACIAL MOVEMENT With diagrams. O. E. GILBERT	333
THE TORONTO MEETING OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE	247
THE GREAT UNMAPPED AREAS ON THE EARTH'S SURFACE AWAIT- ING THE EXPLORER AND GEOGRAPHER J. SCOTT KELTIE	251
THE COMPASS IN MODERN NAVIGATION. O. W. LITTLEHALLE	266

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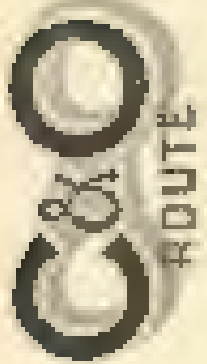
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	SCORE	TOTALS	TRUMP	OPPONENTS		
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	SCORE	GAIN	TRUMP	GAIN	SCORE	
1						1
2						2
3						3
4						4
5						5
6						6
7						7
8						8
9						9
10						10
11						11
12						12
13						13
14						14
15						15
16						16
17						17
18						18
19						19
20						20
21						21
22						22
23						23
24						24
TOTALS			TOTALS			
			150			



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# National Geographic Magazine

VOL. VII

SEPTEMBER, 1895

No. 9

## THE GREAT LAKES AND THE ICE AGE MOVEMENT\*

By G. K. GILBERT

*U. S. Geological Survey*

The history of the Great Lakes practically begins with the retreat

of a low glacier. A great stream from the Erie basin, across the

flowed to the Mohawk valley

formed by their waters. Several of these sandy lines have been

\* Published by permission of the Director of the United States Geological Survey.

and replaced them must originally have been level, and their

present shore-lines are not nearly parallel, and their gradients vary from place to place, ranging from a few inches to three or four feet to the mile.

These were formed one at a time, and the first to appear was the Erie basin. It was much smaller than the modern lake, because the land was then comparatively low at the north-east. Its outline is approximately shown by the dotted dotted line of the accompanying map. Instead of reaching from the site



FIG. 1. APPROXIMATE AND MODERN OUTLINES OF LAKE ERIE.

The broken lines show the positions of the shores at two epochs of the lake's history.

site the present city of Erie, and it was but one-sixth as large as the modern lake. Since that time the land has gradually risen at the north, causing the basin toward the south, and the

created by another dotted line.



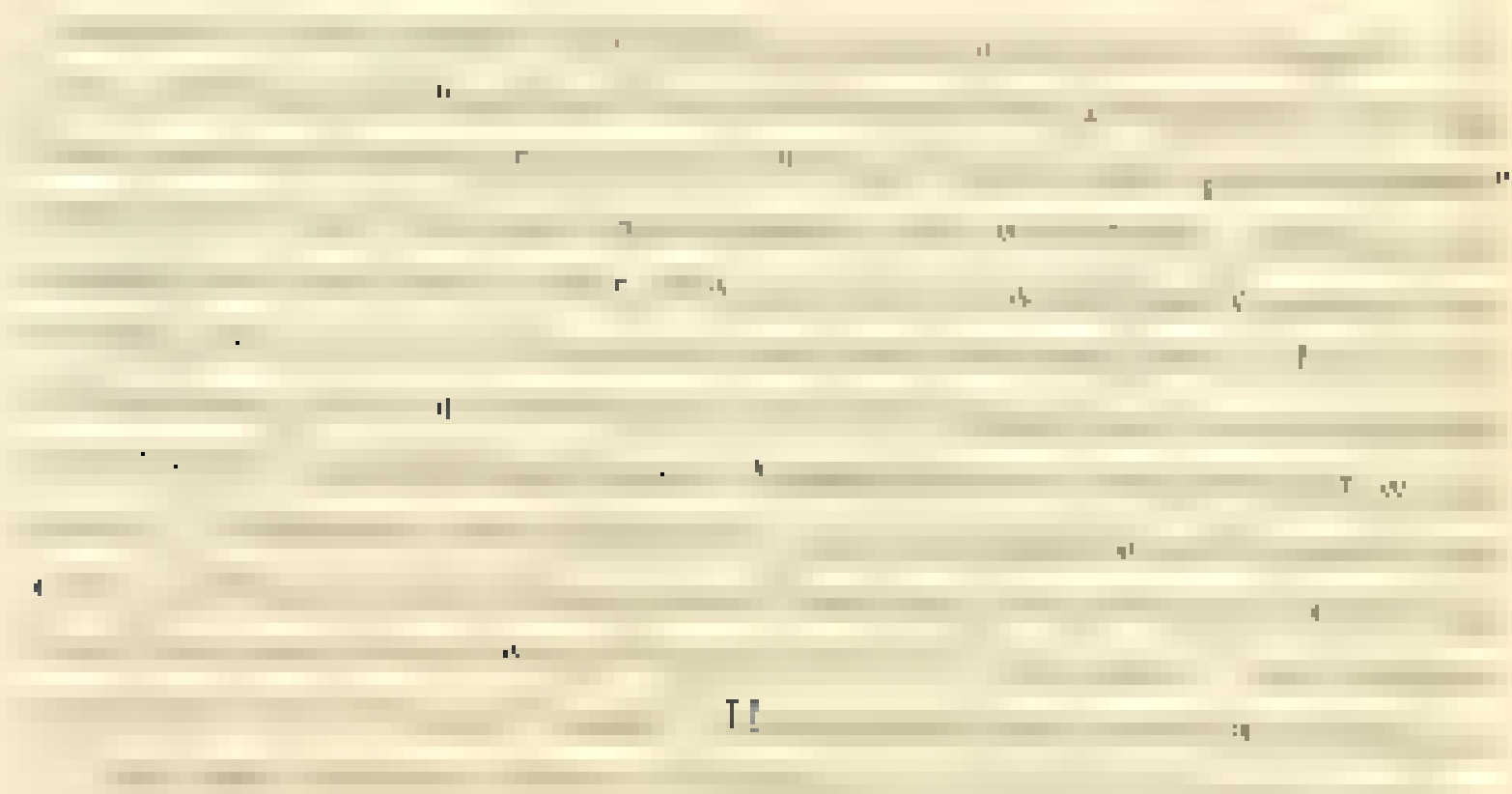
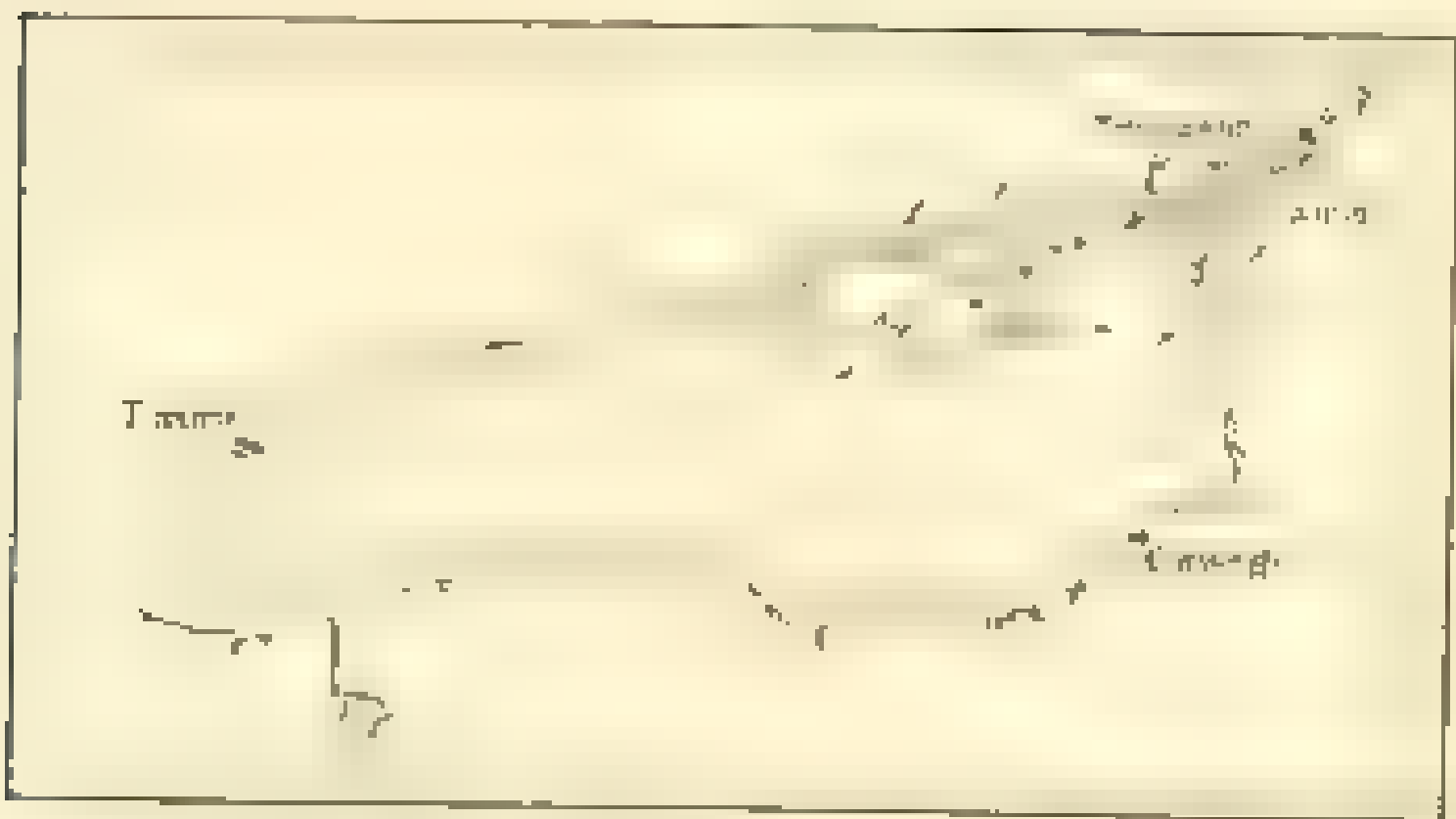


Fig. 12. The original extent of the lakes.



The broken line shows the original extent of the lakes.

There is some reason to think that the upper lakes, Huron, Michigan, and Superior were at first open to the sea, so as to constitute a gulf, but the evidence is not so full as it is of Lake Erie. When the normal lacustrine condition was established.

shores of Lakes Erie and Ontario, but lies chiefly above the

present water surfaces. It has been recognized at many points

has a remarkably uniform dip, at 7 inches or more, in a southe-  
 west direction, or more exactly, S. 27° W. As will be seen

the surface of Lake Michigan near Green bay, and below the



FIG. 1.—THE SHORELINE OF LAKE MICHIGAN AFTER THE  
 THE SHORELINE IS SHOWN BY THE DOTTED LINE

surface of Lake Huron just north of Saginaw bay. The south-  
 ward tilting of the bed, involving the uplift of the point of

March and the water overtook on the latter and then  
 then abandoned and a consequence of the uplift caused the

ing the St. Marys river into existence, and eventually the present condition was reached.

of the Niagara river that the Niagara time estimates, based on the erosion of the gorge by the cataraacts, can be applied to the Great Lake Erie has existed approximately as long as the Niagara river, and its age should probably be reckoned in tens of thousands or hundreds of thousands of years. Lake Ontario is much younger, and that can be said of the beginning of Great Lake Superior is that it came long after the beginning of Lake Erie, but the date of its coming through the transfer of water from the Madison to the St. Clair, is more definitely known. That event is estimated by Taylor to have occurred between 5000 and 10000 years ago.\*

The lake history that briefly sketched is characterized by a progressive change in the attitude of the land beneath them, and a climatic portion of the region becoming progressively more and more toward the northwest. The great change, from Great Lake Superior to Great Lakes Superior-Michigan, and Huron, involving an up-throw of more than 100 feet, has taken place within so short a period that we are naturally led to inquire whether it has yet ceased. Is it not probable that the up-throw is rising at the north end of the lakes are still occurring along their northern shores? J. W. Spencer, who has been an active explorer of the glacial lakes and has given much study to related problems, is of opinion that these events are not over, he is, and, indeed, that they will result in the restoration of the Chicago outlet of Lake Michigan and the drying of Niagara!

The importance of settling this question by actual measurement was a presupposition necessary to the work of the present author. I am a fortunate set of observations to that end. Finding in this, I undertook a new and extensive investigation, which began with the examination of existing records of lake height as recorded by gauge readings, and was continued by the establishment of a number of gauge stations in 1896. To understand fully the nature of this investigation it is necessary to consider the height of that area for it is well known that it is to what the lake water is subject.

\*The work of Thomas Morgan, Jr., A short history of the Great Lakes, 1896, p. 100.

1896 Ann. Ass. Adv. Sci. vol. 11, p. 240.

If the volume of a lake were invariable, and if its water were in perfect equilibrium under gravity, its surface would be constant and level, and any variation due to changes in the height of the land would be easily detected and by observation on the position of the water surface with reference to the land, and if these conditions are never changed in the course of the longest lakes, where the variations are continually continuing, the water is always in motion.

The investigator therefore has to arrange his measurements so as to be in a position to effect of such changes. Consider first the influence of wind. The friction of the wind on the water produces waves. These are temporary and practically vanish in the case of calm, but perpetual groundswell of the ocean is not known in the lakes. The action of the wind on the water mass drives the water forward, producing currents. The water thus driven against the opposite shore returns by undercurrents by the internal action of the water resists and delays the return, and there is consequently a heaping of the water against the shores and a corresponding lowering of its level on the other.

During great storms there is sometimes supposed to be several feet, reaching a maximum in Lake Erie, in October, 1880, a westerly gale is reported to have raised the water 6 feet.

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During great storms there is sometimes supposed to be several feet, reaching a maximum in Lake Erie, in October, 1880, a westerly gale is reported to have raised the water 6 feet.

changes of level are much smaller, but they are none the less appreciable, and they have even been detected in the case of the gentle "land and sea" breezes which in calm weather are created by the diurnal cycle of heating and cooling of the land.

The water is always under atmospheric pressure. If the air were equally on all parts of the lake surface the equilibrium of the water would not be disturbed; but the pressure is never uniform. As shown by the isobars on the daily weather map, there are considerable differences of pressure from point to point and with the height of the air. The Great Lakes have an average of several tenths of a barometric inch. A difference of one hundredth of an inch high weighs as much as a column of water 1 3 inches high; and when ever the atmospheric pressure at one point on a lake exceeds the pressure at another point by the height of a barometric inch the water level at the first point will correspondingly be raised lower than the water level at the second point. When a current is established over the water surface is a result of the

\* See also vol. V, II, pp. 24, 25. The effect of a storm on the other lakes is also observed. Report of the U. S. Army, Dept. of the Interior, U. S. Army, vol. 1, part 4, pp. 115-116.



the actual observer. Such sudden and temporary variations of

direction, except that they are broad and slow, and these waves do not only travel to all parts of a lake but are continued by reflection, so that a disturbance at one point is felt on the water surface throughout and for a considerable period. The passage of a great number of these waves associated with ordinary cyclonic storms and the irregular gale winds are also noticeable throughout the whole body of the lake in motion, so that it always appears to slide or roll to and fro like a swinging water in a tub or basin, and these swinging motions are of a continuous nature. In the

case of the lake over the intervals from sunset to midnight. Such

minutes to several hours, are called *seiches*. The range of the tide is usually a few inches, but at the ends of lakes it is more than a foot or more.

The lakes, like the ocean, are swayed by the attraction of the sun and moon. The effects are in relation to the distance of the moon, and are even smaller as compared to the ocean, but they are still measurable. At Milwaukee the low tide rises about 1 ft. 14 in. more than an inch and the high tide a half inch. At Chicago and Duluth the low tide runs up to an inch and a half and the combination at new and full moon to three inches.

Water is continually added to each lake by rivers and creeks, but the rate is not uniform. Usually a few freshets occurring within a two or three weeks contribute more water, and once during all the remainder of the year. Water is also added in an irregular way by melting snow falling directly on the lake. It is subtracted by evaporation, the rate of which varies greatly, and the overall result varies within moderate limits. The volume of water so added to the lake, being subject to these annual gains and losses, is itself somewhat irregular. The height of the water surface therefore is a sea. In average years the variation for Lake Superior is 17 inches; for lakes Michigan and Huron, 12 inches; for Lake Erie, 14 inches, and for Lake Ontario, 16 inches. Low water occurs normally in January or February for all the lakes except Superior, where it occurs in March. High water is reached sooner in the lower lakes, June



1

$Y Y'$ , and the level is measured as of  $A$  above  $Y$  and of  $B$  above

the height of  $A$  and  $B$ , and if earth movement occurred the change in the relative height may be shown by the difference in the two results of measurement.

As the water is not not at  $L$ , the actual point on the mean surface of level from  $A$  and  $B$  to the water does not exist, and it is necessary to determine from a level on the actual water surface what would be its position if established. Such observations are made by means of gages. These

are zeroed by the water, and a graduated scale by means of which the vertical distance of the water surface from the zero is determined.

Changes in the volume of the lake influence all parts of its

surface. In measurements it is only necessary that the gage observations at the two stations be made in series. The effects of wind waves can be prevented by breakwaters. Disturbance is to be

prevented when there is little wind. The effects of light winds can be approximately eliminated by taking the average of many observations, and so can the effects of waves and tides. The effects of differences of atmospheric pressure can be corrected from barometric measurements of air pressure, and the proper corrections

of observations can be obtained by the use of the standard and a forward applying corrections, and the wind and wave effects can be treated in the same way.

In the investigation I was able to make consideration was given to these various sources of error, and it was not practical to take any special measures for avoidance of correction, because the positioning of gages was only partly under my control. Gage stations have been established on the Great Lakes at various times and at various places, and the records of readings have been preserved. In some cases the records of gages were continued by having with them marks of a permanent character, and in a few in-

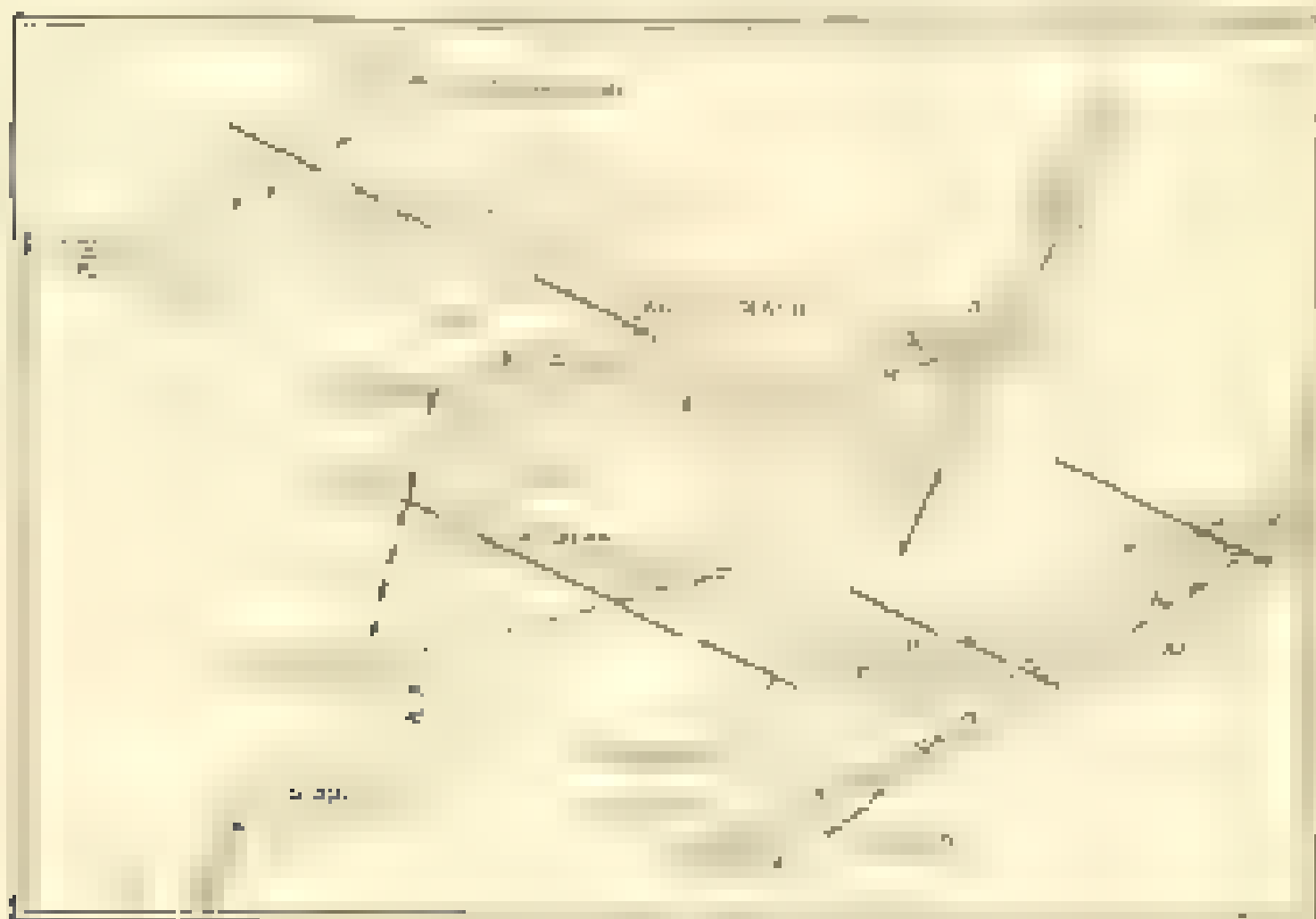
The most important body of information of this character is contained in the archives of the United States Lake Survey, which were placed at my service by the Chief of Engineers, U. S. Army.



ingivalent to A and B of 10 centimeters and been previously determined only or more years ago. At some of these stations

it is not necessary to connect them with the old ones. At all of these observations were made and from July to the day, 1890, and these observations, even a station with the level was marked on the map and the old one was marked with the same color and so as to discover the new one to the next one.

It was necessary to give here the details of observation and computation, as they are later set forth in a paper soon to



The stations are marked by the letters. Broken lines show the work of the party.

be printed by the Geological Survey, but the general scope of the work may be briefly outlined. As the map shown by the figure

shows, it is to test the question of the direction of the current. The most easterly part was marked at Harbor and Charlotte New York, connected by the water surface of Lake Ontario. From observations by the U. S. Lake Survey in 1874 it is known that a bench mark at the light-house at Charlotte was then 18.541 feet above a certain point on the shore. The same point was then 18.541 feet above a certain point on the shore.

at the head of the Western canal, as compared to a point in Cincinnati, Ohio, rose 230 feet, or nearly three inches. Between 1870 and 1880 a point at Port Austin, Michigan, on the shore of

of Lake Michigan, rose 41½ feet, or one and one-fourth inches and in the same period a point in Escanaba, at the north end of Lake Michigan, as compared to the same point in Milwaukee, rose 4,141 feet, or about two inches.

There is no one of these determinations that is free from doubt, ~~and~~ <sup>and</sup> ~~any~~ <sup>any</sup> ~~one~~ <sup>one</sup> ~~or~~ <sup>or</sup> ~~other~~ <sup>other</sup> ~~of~~ <sup>of</sup> ~~the~~ <sup>the</sup> ~~ones~~ <sup>ones</sup> ~~on~~ <sup>on</sup> ~~which~~ <sup>which</sup> ~~the~~ <sup>the</sup> ~~rise~~ <sup>rise</sup> ~~was~~ <sup>was</sup> ~~made~~ <sup>made</sup> ~~may~~ <sup>may</sup> ~~have~~ <sup>have</sup> ~~settled~~ <sup>settled</sup> ~~on~~ <sup>on</sup> ~~stakes~~ <sup>stakes</sup> ~~any~~ <sup>any</sup> ~~have~~ <sup>have</sup> ~~been~~ <sup>been</sup> ~~made~~ <sup>made</sup> ~~in~~ <sup>in</sup> ~~the~~ <sup>the</sup> ~~ear~~ <sup>ear</sup> ~~or~~ <sup>or</sup> ~~evening~~ <sup>evening</sup> ~~when~~ <sup>when</sup> ~~there~~ <sup>there</sup> ~~was~~ <sup>was</sup> ~~no~~ <sup>no</sup> ~~light~~ <sup>light</sup> ~~of~~ <sup>of</sup> ~~subject~~ <sup>subject</sup> ~~of~~ <sup>of</sup> ~~the~~ <sup>the</sup> ~~rise~~ <sup>rise</sup> ~~is~~ <sup>is</sup> ~~to~~ <sup>to</sup> ~~be~~ <sup>be</sup> ~~done~~ <sup>done</sup> ~~even~~ <sup>even</sup> ~~a~~ <sup>a</sup> ~~test~~ <sup>test</sup> ~~and~~ <sup>and</sup> ~~there~~ <sup>there</sup> ~~are~~ <sup>are</sup> ~~various~~ <sup>various</sup> ~~other~~ <sup>other</sup> ~~possible~~ <sup>possible</sup> ~~sources~~ <sup>sources</sup> ~~of~~ <sup>of</sup> ~~error~~ <sup>error</sup> ~~to~~ <sup>to</sup> ~~which~~ <sup>which</sup> ~~no~~ <sup>no</sup> ~~checks~~ <sup>checks</sup> ~~can~~ <sup>can</sup> ~~be~~ <sup>be</sup> ~~applied~~ <sup>applied</sup>, ~~on~~ <sup>on</sup> ~~the~~ <sup>the</sup> ~~fact~~ <sup>fact</sup> ~~that~~ <sup>that</sup> ~~the~~ <sup>the</sup> ~~measuring~~ <sup>measuring</sup> ~~is~~ <sup>is</sup> ~~in~~ <sup>in</sup> ~~the~~ <sup>the</sup> ~~taking~~ <sup>taking</sup> ~~is~~ <sup>is</sup> ~~not~~ <sup>not</sup> ~~free~~ <sup>free</sup> ~~from~~ <sup>from</sup> ~~errors~~ <sup>errors</sup> ~~caused~~ <sup>caused</sup> ~~by~~ <sup>by</sup> ~~heavy~~ <sup>heavy</sup> ~~responses~~ <sup>responses</sup> ~~and~~ <sup>and</sup> ~~in~~ <sup>in</sup> ~~the~~ <sup>the</sup> ~~reading~~ <sup>reading</sup>. ~~The~~ <sup>The</sup> ~~confidence~~ <sup>confidence</sup> ~~is~~ <sup>is</sup> ~~materially~~ <sup>materially</sup> ~~affected~~ <sup>affected</sup> ~~when~~ <sup>when</sup> ~~the~~ <sup>the</sup> ~~averaged~~ <sup>averaged</sup> ~~results~~ <sup>results</sup> ~~are~~ <sup>are</sup> ~~reduced~~ <sup>reduced</sup> ~~to~~ <sup>to</sup> ~~a~~ <sup>a</sup> ~~correlation~~ <sup>correlation</sup> ~~is~~ <sup>is</sup> ~~not~~ <sup>not</sup> ~~compared~~ <sup>compared</sup>.

*Summary of Duration, Time Interval, and Measurements of Inflow of Earth Movements*

	$\frac{1}{2}$ in.	$\frac{1}{4}$ in.	$\frac{1}{8}$ in.	$\frac{1}{16}$ in.	$\frac{1}{32}$ in.	$\frac{1}{64}$ in.
	Feet	Feet	Feet	Feet	Feet	Feet
Stations in the and the lake	83	24	22	104	117	18
Port Austin and Milwaukee	230	190	20	17	10	00

The statistics of the several pairs are also affected similarly with the directions of the lines connecting them in the various angles with the theoretic direction of tilting and the same intervals

may lie in the lowest direction S. 27° W. In the south end in

length of the rods of a line 14 miles long does up necessarily

Compared in this way, the results are remarkably harmonious, the computed rates of tilting ranging only from 0.37 foot to 0.46

There is very little record of the slow tilting of the Great Lakes bearing plain

tilting fast

logic model, or which has been verified by measurement. It is proper to note that the fundamental idea was anticipated much earlier by G. H. Stanton, a Wisconsin surveyor. In a paper read before the American Association for the Advancement of Science in 1889 he cites observations

steadily higher at the west end while it was unusually low at the east, and he infers that the land is not stable.

to one another. All points southwest of it are lowered, those to the northeast are raised. The water, always holding its surface level and always regulated in volume by the discharge at the mouth of the St. Lawrence, is thus lowered in the lower part of the lake. The water level at the mouth of the St. Lawrence is not lowered, but the water is encroaching on it from the lake. The result is a change in the water level at the mouth of the St. Lawrence.

Lake Ontario has altogether no change of the discharge of the St. Lawrence, and the water is encroaching on it from the lake. The result is a change in the water level at the mouth of the St. Lawrence.

St. Lawrence has 5 or 6 inches per century

the consequent amount lowering of the mean water surface is

for the mouth of the French river on Georgian bay. In Lake

At Lac Seul the estimated loss of the water is 4 inches per century, at Milwaukee the estimated rise is 5 or 6 inches, and at Chicago between 5 and 10 inches.

These slow changes of mean water level are connected from

the variations of volume, but they are worthy of consideration

moment to a large community. The city of Chicago is located

some use of protection are imperatively demanded



Looking to the present and future, we may estimate the late glacial period as follows:

Now, as is readily mentioned, is an old channel caused by the outlet of a glacial lake. The bed of the channel at the summit of the pass is about 2 feet above the mean level of Lake Michigan and 5 feet above the highest level. In 500 years

1,000 years it will be continuous. In about 2,000 years the mis-

western outlet at Chicago and the eastern at Buffalo. In 2,000 years the Niagara river will have become an independent stream and in 3,000 years its water will have been diverted to the Gulf of Mexico.

#### ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

If the British Association for the Advancement of Science has never yet come itself to the honor of electing a president, or as its President, it at least is not open to the reproach of neglecting so important a department of knowledge as that which is connected with the education of our youth and the general condition of our government. Throughout its entire history of 75 years the Association, as great geographical conferences, its proceedings, and there have been few distinguished explorers who have not reserves, some of the most interesting and

notable body. Just 40 years ago, in the city of London, it was to see and hear Livingstone that people crowded into the hall assigned to Section B. Fifteen years later, at Brighton, before an equally large and brilliant assemblage, Mr. Stanley narrated the thrilling story of his search for the great missionary-laborer in the waste of equatorial Africa, and almost every Arctic ex-

## THE BRITISH ASSOCIATION

tures and his discoveries before the British Association.

If the recent Toronto meeting was not remembered for any

particular contributions to geographic science. The subjects of the

with the geographic problems of the future and set forth in ad-

remote parts of the world

Dr Kew's address was delivered on August 19, and in the

John, of London, presented the sixteenth report of the Committee

Mr E. De laune Morgan, of London, read a paper on Nova Zem-

tion included a paper by Prof Richard E. Dodge, of the University

a paper by Mr E. C. Havensham on 'The Kingdom of the Isles' p. 111

July and August numbers of the *Geographical Journal*.

Library of the United States

Vol. 1

of London and The Direction of Lines of Structure in Paris.

Shortly after the escape of its member

Mr. H. C. Harvard, spoke on the importance of geography as a

illustrative of geographical scenes and conditions.

meeting. In the Section of Mathematics and Physics, on August

and marine culture. On the same day, in the Section of Zoology,

Mr. Agulh, in the Section of Mathematics and Physics, on

which the Region offers to Climatologists and Naturalists.

In the Section of Meteorology, on August 21, Mr. H. Napier

visited Japan in June, 1896

to the geographer, especially on August 23, when the presence

contact, opened by Prof. F. W. Loomis, of Harvard

are of greatest value and are available for the purpose

J. H.

## THE UNCHARTED AREAS ON THE EARTH'S SURFACE AWAITING THE EXPLORER AND GEOGRAPHER\*

By J. SCOTT KELLER, LL. D.

*Secretary to the Royal Geographical Society, Editor of the Geographical Journal  
and of the Geographical Year-Book, etc., etc.*

We have this year an exceptional circumstance. To those

as it applies to the publication of the Society

\*-The publication of this volume is a result of the Geographical Society of the British Empire  
which for the Advancement of Science at Toronto, August 18, 1895

## 99. THE UNEXPLORED AREAS ON THE EARTH'S SURFACE

the past. We have all of us been celebrating the sixtieth year  
Canada and the United Kingdom have entered into the present  
age for the expansion of the globe.

Just as it has been made known to us the truth of  
the discovery of that continent were sixty years ago of the most

amazing. And I cannot give you of the great progress which has

now dawned to our science and opened up innumerable fields of  
research.

I have thought, then, that the most useful and most manage-  
able as well as able as to do this work, by

AND

Since then the energy of India, one of the greatest

enterprises undertaken by any State, has been completed, and it is

the mountains of the region.

The most important desiderata, so far as pioneer exploration of Asia is concerned, may be said to be confined to two regions, in southern and central Arabia, there are tracts which are or

may be said to be a sandy desert. At the same time it is, in the south at

of rich cultivation and whose ruins—in the late Sir Thomas Herbert

and, political, and religious—which might be met with in a com-

prising story

the north and east. Lines of exploration have in recent years

the late, Welby and Macdonald. From the results obtained by explorers we have formed a fair idea of how the most arid, the highest, and the most inhospitable of areas in the world. A

most interesting details as to its geological history

#### THE PERSIAN GULF

The region lying to the north of the Hinduayan range and to the south of the parallel of 10° has as almost a blank on the map, and there is ample room here for the enterprising pioneer. The northern city of Lanna is at present the goal of several adventures, though as a matter of fact we even at have much to learn in addition to what has been revealed in the interesting narrative of the native Lanna traveler, Chuan Lin Das. The maps of



most mountain region on the north and east. It has furnished a

approach to it from the east, through a Szechuan, an interesting description of the romantic scenery and the interesting people. The inhabitants have as yet a strong desire to learn more. On the south-east of Tibet is the remarkable mountainous region, consisting of a series of lofty parallel chains, through which run the upper waters of the Yangtze, the Mekong, the Irrawaddy, and the Salween. It probably does not reach far into the range. But it will be seen by a glance at a map that the upper waters of the other rivers are carried far into the heart of the mountains. But these upper-

controversy. There is plenty of work here for the explorer though the difficulties physical and political, are great.

But apart from these great unexplored regions there are many tracts to be explored up in other parts of Asia and regions which,

mountain. There is the mountain track between the Zaskashan river and the head of the course of the Salween, a tributary of the Irrawaddy,

and the Yangtze river inhabited, and that at no very remote period, it is almost surrounded by the Tartar, and on its eastern edge lies

of recent investigations. As regards the Yangtze, a Voyage of the Formosa will enter the Szechuan coast is in it is perfectly a appeal. Of course this is a difficult task, but it is one in which the Russian government ought to be equal. It has on paper

but our knowledge of its mountain ranges and of its great river courses is to a large extent extremely vague. All this awaits careful survey. In north-eastern Manchuria and in many parts of

river systems to be surveyed. In the Many peninsula and in the great array of islands in the east and south-east of Amur, Sakhalin, Japan, the Philippines—much work still remains to be done. Thus for the coming century there will be no lack of

work for explorations in Asia and plenty of material to occupy the attention of our geographo-historical societies.

#### THE AFRICAN

Coming to the map of Africa, we find the most marvellous transformations undergone in the last sixty years, and mainly during the last forty years, dating from Livingstone's historic journey across the continent. Though the north of Africa was the home of one of the earliest civilisations, and though on the shores of the Mediterranean were the monuments of a far more illustrious and Roman work for our races, it has only been within the last century of many of us that the interior of this continent, from the Sahara to the confines of Cape Colony, has ceased to be an unexplored blank. This blank has been filled up with a wealth of geographical facts, of great rivers and lakes and mountains, of vegetation and climate and human features, of the whole continent, with a few unimportant exceptions, has been parcelled out among the powers of Europe; but much still remains to be done ere we can form an adequate conception of what is in every respect the most interesting and the most important of the continents. Many curious problems still remain to be solved. The pioneer work of exploration has to a large extent been accomplished; large tracts have been run in and mapped out; the main features have been marked out, but between these tracts the land meshes remain to be filled in, and to do this will require many years of careful exploration. However, there still remain one or two regions that afford scope for further exploration in pioneer.

To the south of Abyssinia and to the west and northwest of Lake Chad, and to the Upper Nile, is a region of considerable extent, which is as a proportion of unknown. Again, the western Saharan coast is a large unexplored area, traversed mainly by the immense Sahara, into which no one has been able to penetrate, and of which our knowledge is extremely scanty. Even in the central Sahara there are great areas which have not been traversed, while in the far south-west there remains to be done

10

and geological studies, but they deserve careful investigation, not only that we may ascertain their actual present condition, but in order to see that we may try to discover some clue to the past history of this interesting continent. Still, it must be said that the great features of the continent have been so fully mapped during the last half century that what is required now

is mainly the blighting of our maps. This is a process that re-

quite recently an English traveler Mr Cooper found not far from

our maps. If only the obstructiveness of the Turkish Empire could be overcome, there is a rich harvest for any one who would work with patience and intelligence. Even the interior of

The French in both Tunis and Algeria are extending their knowledge outward.

#### OPPORTUNITY FOR THE FUTURE

are doing much to acquire a knowledge of their territories. Their

the fauna, the flora, and the economic resources. Just as the

and the map of Africa is being gradually filled up. But what

was so work on the Great Salt valley is one of the most valuable material added to African geography ever made. If men of this stamp would settle down to regions like that of Mount Kauerz or Lake Chad or the region about lakes Bangweulu and

to know the general facts of its geography, as well as to the economic interests of Africa, would be great. An example of work of this kind is seen in the discoveries made by a young biologist trained in zoology and a geographer, Mr Moore, on Lake Tanganyika.

Mr Moore's examination is especially of a salt-water type. Mr Moore, however, is inclined to maintain that the present connection of this part of Africa with the ocean was not by the west, as Joseph Thomson supposed, but by the north, through the

careful examination of Lake Chad as the crucial test of the

only to provide results of the highest importance.

#### CLIMATE OF THE COUNTRY

But, there are other special problems connected with this

development of Africa, is the problem of acclimatization. The

of the world. Indeed, that Central Africa was a very  
potentials, and therefore we look forward to the exact results

to do. We can only go to work experience daily until we know  
solve the problem of acclimatization when we have the exact fac-

or, opinion of those who have had actual experience of African

of work in tropical Africa, it will never be possible to estimate

of India.

So far, men, and experience has shown that white people can  
can hope to settle in Central Africa as they have settled in Cana-  
ada and the United States and in Australia, and make it a per-  
son and a home for new generations. Even in such favorable

children can not be reared over a certain age, they must be

and really. No country can ever become the true home of a  
people if the children have to be sent away to be reared. Still,  
it is true our experience in Africa is limited. It has been main-  
tained that it will be possible to adapt Europeans to tropical

Africa by a gradual process of migration. There has not been time

to infiltrate and further into the heart of the continent. The expected long one it would be—ought to be tried, but it is to be feared that the authorities would be a case decided of a disease characteristic which have made Europe what it is.

Another young Italian physician, Dr. Sarrasin, has recently

stated that it has taken six centuries in Europe to discover our hidden enemies, the principles of the various diseases to which northern humanity is a prey, and to meet them and conquer them. In Africa we have a totally different set of enemies to

oppose these forms of malaria, anaemia, and other diseases characteristic of tropical countries. He admits that these are more or less of us to limit, to the nature of the soil and other things

in the way of working we should be in a position to meet them and

the European population. What is wanted is a series of carefully conducted experiments.

I have referred to the plateau highlands. In British East Africa

above sea level. The world may become so full that we may be forced to try to utilize these highly tropical regions as homes for

human overpopulation. As one of my present visitors in this chair (Mr. R. Sarrasin) tried to show at the last meeting some years ago, the population of the world would have more than doubled in a century, and about 180 years hence will have quadrupled. At any rate, there is a problem of prime importance for the geographer of the coming century to attack. With so many over-crowded and over-crowded white man in Africa, it is not to be difficult to imagine a time when we might help toward the solution

## NORTH AMERICA

I have dwelt thus long on Africa, because it will really be one of the great geographical problems of the coming century. Had it been as suitable as America or Australia, we may be sure it would not have remained so long neglected and unexplored by the European peoples as it has done. Unfortunately for Africa, just as it had been circumnavigated, and just as Europeans were be-

way into the interior, Columbus and Cabot discovered a new

world to reach. That discovery postponed the big attempt to explore

it 40 years ago and the stagnation of Africa, which has been known to Europe so long before the beginning of history. During these 40 years South America at least has been very thoroughly explored. The two great nations which invade North America

supplying the world economy with raw materials of the gold, silver, and other resources.

done by the survey of Canada under Sir William Logan, for many years has been a constant. Dr. Logan himself has not been able to forget that under the same department in the execution of

the production of the map, though much has been done, there remains to be done. There are large areas which have not as yet been roughly mapped. Within quite recent years we have and now are also seeing at its best by the work of Dawson and Ogilby on the Yukon, Dr. Bell in the region to the south of Hudson Bay, by the brother of Tyrrell in the barren lands to the west of the same bay, by other men beyond the shores of the Ottawa and by Lewis in Labrador.

But it is not so long since that Dr. Dawson, in review of what remains to be done in the Canadian way of even further exploration pointed out that so much of the land on square miles still remained to be mapped. Apart from the uncharted white regions in the north, there are, as Dr. Dawson pointed out, considerable areas which might be taken as profitable areas of land and water the amount of which we know little, such areas as those which have been recently mapped out in the north of the

survey by Mr. Keiser and beyond the Ottawa by Mr. Sullivan.

so far almost untouched. A very great deal has been done for the survey of the rivers and lakes of Canada. I need hardly say

the study of many problems in physical geography—last and

of Lake means, the course of river beds, the elevation of coast lines. Many of both in Canada and the United States have now

into publications a wealth of data has already been accumulated of a degree to do to the geographer.

#### UNITED STATES

Every geologist and geographer knows the important work which has been accomplished by the various surveys of the United States, as well as by the various State surveys. The

a century, mapping not only the coast but all the navigable rivers. The Lake Survey has been doing a similar service for the shores of the Great Lakes of North America. But it is the work of the Geological Survey which is best known to geographers—a survey which is really topographic, and as well as geologic, and which, under such men as Hayden, King and Powell

a survey has been placed on a more systematic basis so that a scheme for the topographical survey of the whole of the territory of the United States is being carried out. Extensive areas in various parts of the States have been already surveyed on different scales. It is to be hoped that in the future, as in the past, the geologists who are employed on this survey work will have opportunities of working out the physiography of particular areas, the past and present geography of which is of natural scientific interest. Of the complete exploration and mapping of the North American continent we need have no apprehensions; it is only a question of time, and it is to be hoped that one of the governments responsible will now put into

importance.

#### CENTRAL AND SOUTH AMERICA

It is when we come to Central and South America that we find ample room for the unexplored. In Mexico and the Central American States there are considerable areas of which we have little or only the vaguest knowledge. In South America there is really more room now for the pioneer explorer than there is in Central Africa. In recent years La Argentina developed

new territories, where on certain amounts of good work has been

done by explorers. Along the great river courses our knowledge is

limited, lying between the rivers are almost unknown. In Brazil

the Rio Negro we have much to learn, while on the West Coast

systematic exploration is wanted, exploration of the character

and of the region.

There is an enormous area lying to the east of the northern

lying between the Rio Negro and the Atlantic which is known.

In short, in South America there is a wider and richer field for

exploration than in any other continent. But no more rush



rovers ought to be able to bring back satisfactory information on the geology of the country traversed, and of its fauna and

flora; and there in former epochs are of the highest interest. Moreover, we have here the remains of extinct civilisations to

which we may apply careful investigation.

#### AFRICA

The southern continent of Australia is in the hands of men of the same type as those who have developed the same characteristics

characteristics of that continent. The five colonies which cover the continent have the same characteristics of the continent of the continent.

of the continent is the water supply quite adequate; in all are

able. This desert area has been crossed by explorers, at the ex-

there with spinifex and scrub which are useless. There are

which are essentially from the same source, have been found along the routes that have been explored.

which in recent years have connected various parts of the continent with the

look for the richest results in the future. There remains much

face there is an immense store of water. In one or two places in Wales, this supply has been tapped with satisfactory results;

#### POLAR EXPLORATIONS

the North Pole yet to be done—so far, at least, as the Old World side of the Pole is concerned. That some one will reach the Pole at no distant date is certain; Nansen has shown the way, and the great untold curiosity of humanity will not rest satisfied till the goal be reached. But Arctic exploration does not deal with the attainment of the Pole. Europe has on her share on her own side of the Pole, what side of the world which forms the hinter-

lands, Franz Josef Land, Nova Zembla, and the New Siberian Islands. To the north of America we have an immense peninsula, the actual extent of which is unknown. Nansen and

do for that half of the North Polar region what Nansen has done

ther than we find them on our maps. Whatever be the case, it is important, in the interests of science, that this section of the

coast extend all round the Pole.

It is stated that the gallant Lieutenant Penny has organized a magnificent expedition. Let us hope that he will be able to carry out his schemes. Near time should Canada look on with indifference? She is at the head of a great and prosperous nation; she has shown the most conspicuous zeal in the exploration

those of other countries. Her press is of a high order, and she has made the highest use of a literature and an art of her own.

many contributed to it for the name of Great Britain is extensive than those enterprises which for centuries have been venturing from

the between her and the Pole? I venture to throw out these

honor and glory of the great Canadian Doctor.

#### THE ATLANTIC MARCH

Not only has an interest in Arctic exploration been revived, but in Europe at least an even greater interest has grown up in the exploration of the region around the opposite Pole of the earth of which our knowledge is so scanty. Since Sir James

and with the conditions of herent, even those which surround the North Pole. Instead of an almost endless ocean, it is but even

we see that it is now we have a fairly adequate idea of what

are the real icebergs. We want to know what is the extent of each land, what are its glacial conditions, what is the character of its geology, what evidence exists as to its physical and geological conditions in past ages? We know there is one lofty, active volcano. Are there any others? Moreover the science of terrestrial magnetism is seriously impeded in its progress because the data in that department from the Antarctic are so scanty. The sea around this continent requires to be investigated not only as to local depth, the temperature, and the life. We have here, I repeat, the most extensive, unexplored area on the surface of the globe.

complete the work begun by Ross sixty years ago, and to supplement

upon an enterprise which might involve the services of a few naval officers and men. We need not unduly hesitate; but

experienced men for an Antarctic expedition under our own auspices. It is felt that Antarctic exploration is peculiarly the

task of one of the greatest geographical powers of the future,

to say. It may be mentioned that a small and well-equipped

on a much larger scale.

with our science has to lead not only to the lands of the

that is there, so far at least as Antarctic is concerned. The department of meteorology, by a constantly advancing investigation, in-

deed. It may be said to have come definitely into being with the famous voyage of the *Challenger*. There had been an expedition for ocean investigation before that, but on a very limited scale.

In test areas, too, we have been able to obtain an approximate

right course and the conditions of movement, of temperature, of

the ocean bed and of the composition of the sediment which covers the bottom. The extent of the knowledge thus secured may

thank Dr J. A. Murray twenty years to bring out.

What is to be done to the ocean, however, to the land. It is only

the attention they deserve.

There has recently been the subject of special investigation—by

study of a special English river system. The work in the last

It is in Germany and in Russia special attention is being given

Lawrence is turned in toward an official publication.

## THE COMPASS IN MODERN NAVIGATION

by G. W. LITTLEHART.

*The Hydrographic Office*

Transoceanic navigation, with all that it has been to the commerce of the world and the development of the civilization of the

the extent of the influence of the compass in human affairs.

skilled and of suitable instruments, and today, by the use of the chronometer and sextant, is a science far less uncertain than it was when it could take the native's word for aught. The latter instrument is however almost useless in the case of the compass, and to preserve the general principle, but to save the

meridian in nature.

Up to the era of iron ships the compass of the mariners compass was as simple as the surveyor's, being influenced by the earth's magnetism alone, but with the growth of iron navigation

and when in their masterly hands it was found that every ship herself becomes a great magnet has it become, as it were, of lesser interest.

It is long been known that the earth acts upon the magnet as does a bar magnet. It is now known that it has definite poles of magnetic strength and is a magnet of itself, so powerful that which may be recognized in general by lines of magnetic intensity passing from one pole and proceeding to the other by

everywhere of itself. Long ago it was known that a century it has been constantly in progress, and it is now known that the elements of the earth, in all its variety of the earth's magnetism as found below at its surface, by lines conceived to be drawn it, on the surface of the globe. The lines passing through all places where

points of the same are called lines of equal magnetic declination.

curved paths to the other and through the geographical poles of the earth. The lines which are conceived to be drawn through

lines of equal magnetic declination. They give the earth at a reference line parallel to the magnetic equator, so that the same as the parallel of declination which is drawn on the geographical equator. The magnetic equator is the line passing through every point where the freely suspended needle rests in a horizontal plane. As we travel from the magnetic equator towards the northern magnetic pole the needle inclines more and

moving the north-south leading component out of its previous position, when the compass assumes a vertical direction. As we have seen, in the northern magnetic pole the same takes place with the  $\pm 45^\circ$  end of the needle.

Similar results may be obtained by carrying a small needle suspended in a magnetic field of a bar-magnet.

As the needle toward the pole becomes more and more, as it does with the bar-magnet, which has a magnetic field that varies in intensity from point to point, so with the earth, whose magnetic field is powerful near the Poles and steadily moderates in strength as the magnetic equator is approached. There is thus a vertical set

in the earth. These are known as truly magnetic lines or lines of magnetic intensity. In general, so long as they follow lines of equal inclination or dip.

often previous to the compass which may be used and thus answer to the values of the magnetic elements are not fixed either as to time or locality, they shift their position nearly daily.

and need to be permanently, with the exception of the secular change, are of such small magnitude that they do not affect the use of the compass on the sea where compass is carried on.

may be drawn so as to hold good for several years from a given epoch.

A freely suspended magnet needle dipping as it does, everywhere except on the magnetic equator, is of no value to guide a ship. The compass needle must be horizontal. This condition is attained by placing the needle on a leading rod that causes the needle to overcome the downward pull of the earth's magnetic field, or by floating the compass suspended in a mixture of water and alcohol. It is, therefore, only the horizontal component of the earth's magnetic field that gives steadiness to the needle of the compass and not a mere direction.

If a wooden ship with no metal other than the copper sheathing, were to sail about the world, her compass would experience only large magnetic phases that result from the action of the earth's magnetic dip—more or less steady, according to

the ship herself would exert no influence whatever. But to understand exactly the idea of guiding a vessel having no magnetism to induce whatever over the globe—a great magnet whose magnetic elements are known—the mariner's compass is employed in guiding a steel vessel, which is a great magnet, whose magnetic elements are ever varying and changing over the globe, a greater magnet.

If a bar-magnet is brought to a horizontal position under a compass needle that has assumed a steady position, when the

needle moves and assumes a position which is the result of the joint action of the earth and the bar-magnet, and with every

passage it will assume a new regular position. It is analogous to the joint action of the magnetism of the earth and the magnetism of the mariner's compass, except the influence of the ship is not yet complemented by the existence, also, of the permanent magnetic elements of the ever-changing magnetic influence resulting from the inductive action upon the "soft" iron of the ship of the field of the earth's magnetism, and the ship's permanent magnetism.

If a cylinder of pure wrought-iron that has not been bar-magnetized is cut very free from magnetism be held vertically in our hand, the upper end instantly becomes a south, and the lower a north pole. If it be reversed, the same result also occurs, so that the upper and lower ends are still as they were before—

where that toward the south becomes a south pole, and where reversed slowly or rapidly in diameter, the foot of

which becomes east and west, and the surface is divided by north and south, and in facing the south by north and south. Again, if it be reversed the head of a ship will be like the cylinder of pure wrought-iron and as susceptible of magnetism in being steered over its ever-changing courses as the cylinder is when turned into different positions. Then as the ship steers north, in the northern magnetism south, but the bow will become the center of north polarity and the stern



measured, as will the north for is shift to the north how the south

become a diagonal from starboard bow to port quarter. When the ship heels most as the starboard side is pierced with south polarity, the port side north, and the neutral line takes a general fore-and-aft direction. Coming to change course to the

are repeated, but this time it is the stern that is a north pole, while the bow is a south pole. At west the conditions at east

colatitude and the port side south polarity. And this transient imbalance is due to the cylinder and the ideal ship is a only due

leaving now the ideal or "soft" iron ship and passing to the

characteristics that make it as permanent and well defined as

nature of her construction

An iron ship, with her frames, plating, decks, beams, stanchions

take and reactionary influences with the hull. However

analytical investigation to reach results to enable the

course, its effect may be considered as taking place in three

Almost all the structural iron of a ship is symmetrically re-

found similarly disposed on the port side; and the problem is simplified to pairs of parallel forces, each pair having its resultant parallel to one of the coordinate axes. The effect of every magnetic particle, whether of permanent or induced magnetism, may be reduced to this condition. If the sum total of all the magnetic forces parallel to each coordinate axis be transferred to it, and the whole be conceived to be concentrated upon the north point of the compass-needle, the entire magnetic power of the ship may be compared to that of three imaginary compound-magnets—one laid horizontally in the axis of  $X$ ; the second, also horizontally, in the axis of  $Y$ , and the third, vertically, in the axis of  $Z$ . By steaming around a circle in the open sea and observing the compass bearing of the sun with the ship's head on equidistant compass courses, and also, at the same times, the astronomical bearings of the sun, the magnetic effect of the ship—that is, of the three imaginary compound-magnets in the axes of  $X$ ,  $Y$ , and  $Z$ —which causes the needle to deflect from the magnetic meridian by different angles at the different headings, can be immediately found, if the variation of the compass due to the geographical locality is known. As the ship makes a complete circle in azimuth, the north end of the needle is drawn sometimes to the right hand of the magnetic meridian and sometimes to the left hand; in the former case the deflection is called east deviation and in the latter west deviation. A table of these deflections, serially arranged, is called a table of deviations of the compass. The harmonic analysis of such a table of deviations consists in representing each of the elementary magnets, whose effects contribute to make up the imaginary compound-magnets, as a separate disturbing cause whose effect upon the compass needle may be represented by a constant multiplied by a simple harmonic function of the compass-azimuth of the ship's head. Adding together the effects of the different disturbing causes, thus represented, and placing them equal to the deviation observed on a certain heading of the ship, a conditional equation may be formed for each of the headings upon which the deviation was observed.

From such a series of conditional equations normal equations may be found by the method of least squares, and from them the harmonic constants which represent the elementary disturbing magnets. Thus it is that from the effect an intelligent comprehension of the cause may be gained.

With these coefficients a navigator may compute beforehand

the value of the deviation to which his compass will be subject on any heading of the ship; but in making long cruises and passing into different magnetic latitudes they require unceasing attention, because some of them represent the effects of the induction of the earth's magnetic field upon the "soft" iron of the ship, and as the ship sails the ocean she passes through ever-varying fields of terrestrial magnetism. Her own magnetism is also undergoing continual, though small, changes due to the wrenching and straining of the ship by the action of the sea. Yet, by examining thoroughly into the harmonic coefficients and by considering the known values of the elements of the earth's magnetism, a careful navigator may predict a table of deviations for his ship and compass in any part of the world.

He will then understand and be prepared for such changes in the ship's magnetism as arise from the heeling of the ship, from change in geographical position, and from alteration in the course after the ship has remained for a long time on one heading, and he may navigate his vessel with the confidence and security that he would have in a wooden ship, for he can at any time correct the course steered by the compass so that the magnetic course actually made good may be laid down upon the chart or used in the calculation of the ship's reckoning, he can correct bearings of the land by the amount of deviation due to the direction of the ship's head at the time they were taken, and if he wishes to shape a course for a port, having found by calculation or from the chart the correct magnetic course to be made good, he can so apply the deviation as to obtain the compass course to be steered.

In many modern ships the deviations are largely reduced by introducing magnets into positions near the compass to compensate for the effects of the ship's magnetism. The analysis of the table of deviations shows that the polar forces acting in the ship may be represented by imaginary magnets, and it is, therefore, certain from well known laws of magnetic action that the effects of these disturbing forces may be neutralized by introducing real magnets whose forces have the same magnitudes but act in the opposite directions.

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